Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone

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Grant #: N000149710279
http://blg.oce.orst.edu/shoaling

LONG-TERM GOAL

Our long-range goal is to improve physical understanding of sea surface fluxes and atmospheric boundary layer development in the coastal zone, improve formulation of surface fluxes and implement the revised formulations into regional and large-scale models.

OBJECTIVES

Our objectives are to attempt to generalize parameterization of the aerodynamic roughness length without inclusion of a full wave model, extend these improvements to heat and moisture transport and set the framework for inclusion of information on wave state. These formulations will be tested in regional models including the case of very thin boundary layers in offshore warm air advection as a difficult scenario, presently poorly simulated by numerical models.

APPROACH

The primary approach is to re-analyze eddy correlation data from SHOWEX and RASEX and incorporate additional data sets from NPS buoys in SHOWEX and near Wallops Island and offshore tower data from the University of Uppsala. Cooperative modeling efforts will be carried out with Scott Sandgathe, Phil Barbour and Roger Samelson at OSU using COAMPS.

WORK COMPLETED

We have evaluated simple formulations of the surface stress using the above mentioned data sets, including careful evaluation of self correlation. Work on assessment of flux errors due to fluctuations of platform height has been completed. The literature survey has been started but not completed.

RESULTS

For the data sets outlined above, the usual formulations for the aerodynamic roughness length based on the Charnock relationship and wave age are dominated by artificial self-correlation. The physical variance explained is small. This dominance remains even after removing cases with short fetch, weak winds and upward momentum flux from the sea surface. In addition, the overall behavior of the

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Form Approved
OMB No. 0704-0188

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1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **College of Oceanic and Atmospheric Sciences,,Oregon State University,,Corvallis,,OR,97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Our long-range goal is to improve physical understanding of sea surface fluxes and atmospheric boundary layer development in the coastal zone, improve formulation of surface fluxes and implement the revised formulations into regional and large-scale models.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Charnock coefficient is sensitive to the treatment of numerous outliers and the method for averaging values of the roughness length over the various records. Part of the large variability of the Charnock coefficient is due to the influence of wave state. Relationships allowing the dependence of the Charnock coefficient on wave age are still dominated by self-correlation. However, inclusion of information on the significant wave height does increase the physical variance explained.

The extreme variability of the Charnock coefficient is also due to anomalously low values in very stable conditions as well as observational problems and deviations from Monin-Obukhov similarity theory, all of which is absorbed in the "backed out" aerodynamic roughness length. Winds following the swell lead to very small values of the aerodynamic roughness length and Charnock coefficient although these results are based on a small subset of the data and require much more careful examination.

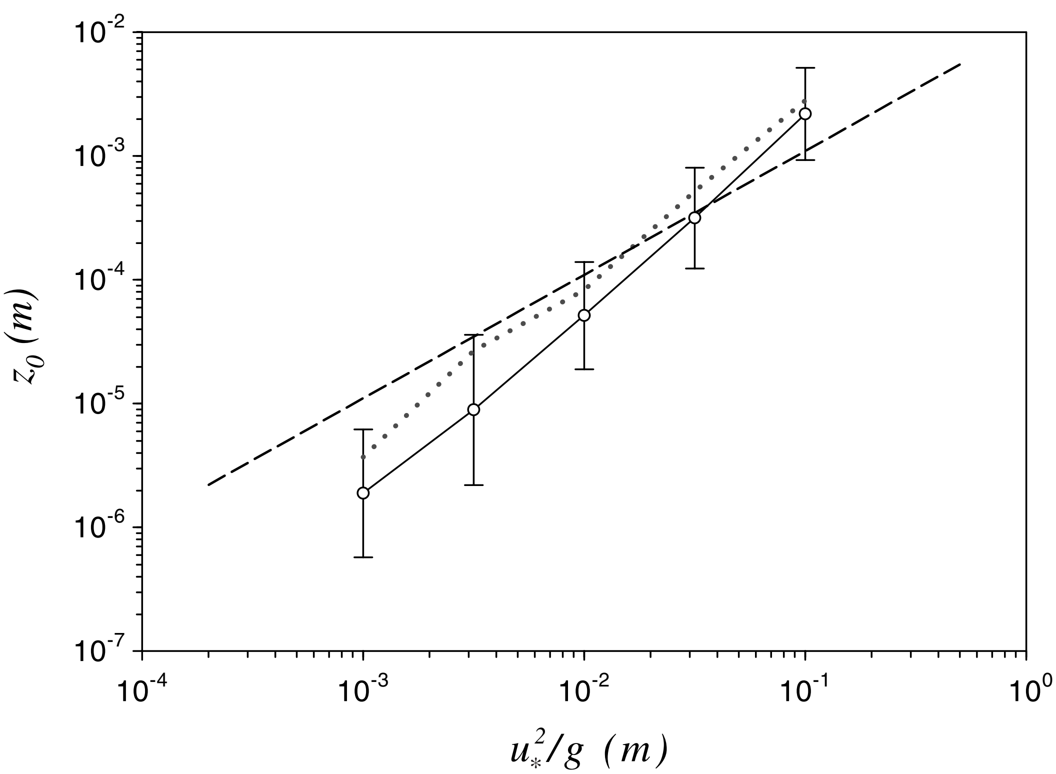

Figure 1: The dependence of the roughness length on u_*^2/g

Figures 1 shows the dependence of the roughness length on u_*^2/g for all of the data sets combined, excluding weak wind cases. The dashed line is the Charnock prediction with a coefficient of 0.011. The error bars indicate one standard deviation. The dotted line represents linear averaging. Standard errors are extremely small because of the very large data set and would not be visible on the plot. The plot shows that the aerodynamic roughness length increases more rapidly with surface stress than predicted by the Charnock relationship (partly due to artificial self-correlation) and that for the present data sets, the aerodynamic roughness length is generally less than that predicted by the usual Charnock relationship. The scatter is large, partly due to effects of wave state.

Unfortunately, most regional and large-scale models cannot accommodate the complexity and computer time required for a full wave model. Formulations based on the Charnock coefficient will probably remain a primary parameterization for closing the surface stress formulation in numerical models even if assigning physical significance to these relationships is tenuous. Collectively summarizing the present data sets suggests using a smaller value of the Charnock coefficient at intermediate wind speeds compared to traditional values of the Charnock coefficient. Restricting the data set further by excluding frequent swell conditions, improves the performance of the simple formulations but swell conditions are common in the coastal zone.

A formulation for the dependence of the Charnock coefficient on wind speed has been developed as a pragmatic "poor man" substitute for information on wave state and other influences causing deviations from Monin-Obukhov similarity theory. Although a substantial improvement upon the specification of a constant Charnock coefficient, this formulation cannot account for major aspects of the influence of wave state and is physically indirect and incomplete.

We have studied the impact of errors due to vertical displacement of platforms resulting from contamination of the computed turbulent fluctuations by mean vertical gradients using LongEZ and ASIS buoy data. Aircraft platform fluctuations for the present data lead to small overestimation of the heat and momentum fluxes for stable conditions and unimportant errors for unstable conditions. For typical record lengths, the magnitude of the displacement flux error is generally smaller than the usual random flux error, where the latter remains nonzero even for stationary platforms. Both random errors are reduced by increasing record length.

The displacement flux error can be theoretically partitioned into a random part (not to be confused with the usual random flux error) and a systematic part. The flux displacement error for short aircraft records is strongly influenced by the random part of the displacement flux error, which is smaller than the usual random flux error. For longer aircraft records, the random part of the displacement flux error decreases and the displacement flux error approaches the small systematic part of the error, typically a few percent of the total flux for stable conditions and less than one percent for unstable conditions. The systematic error tends to increase with stability. The general unimportance of the displacement error for the LongEZ is encouraging since this small aircraft is displaced more by atmospheric vertical velocity fluctuations compared to larger aircraft. Larger aircraft are unable to fly as close to the sea surface and are therefore less suitable for estimating surface fluxes in thin stable boundary layers over the sea. For flight levels closer to sea surface, the flux displacement error is expected to be larger because of larger vertical gradients. Unmanned aircraft may suffer larger platform displacement errors because of larger vertical displacements.

Compared to the aircraft, the buoy errors would be enhanced by stronger gradients at the lower observational levels of the buoy, but are reduced by small magnitudes of the buoy displacement and the small vertical velocities close to the surface. The displacement flux error for the buoy becomes marginally significant only for large wave heights where it averages a few percent.

RELATED PROJECTS

In "Surface fluxes under weak wind conditions" (N00014-01-1-0084), we are analyzing eddy correlation data from the LongEZ from the pilot experiment for the CBLAST weak wind program and making preparations for the intensive period in 2003.

PUBLICATIONS

Mahrt, L., D. Vickers, W. Drennan, H. Graber and T. Crawford, 2002: Fluxes measured from moving platforms. Submitted to *J. Atm. and Oc. Tech.*

Mahrt, L., D. Vickers, J. Sun, T. Crawford, G. Crescenti, and P. Frederickson, 2001: Surface stress in offshore flow and quasi-frictional decoupling. *J. Geophys. Res.*, 106, 20,629-20,639.